ART 34 AMDT

Claims

1. An optical waveguide with multiple core layers for transmitting an optical signal, the waveguide including:
a substrate;
a waveguide core formed on the substrate and comprising a first core layer and a second core layer;
an upper cladding layer embedding said waveguide core;
wherein the first core layer includes a dopant to permit the first core layer to exhibit a photosensitive response, and the second core layer includes a dopant to induce amplification of an optical signal transmitted through said waveguide core.

2. An optical waveguide according to Claim 1, wherein the first core layer includes a germanium oxide to permit the first core layer to exhibit a photosensitive response.

3. An optical waveguide according to Claim 2, wherein the first core layer further includes a boron oxide.

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4. ~~A waveguide as claimed in any preceding claim, wherein the substrate comprises silicon and/or silica and/or sapphire.~~

5. ~~A waveguide as claimed in any preceding claim, wherein the substrate includes an intermediate layer.~~

6. A waveguide as claimed in Claim 5, wherein the intermediate layer includes a buffer layer formed on the substrate.

7. A waveguide as claimed in Claim 6, wherein said buffer layer comprises a thermally oxidised layer of the substrate.

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8. A waveguide as claimed in Claim 6 or Claim 7, wherein the intermediate layer further includes a lower cladding layer formed on said buffer layer.

9. A waveguide as claimed in any of Claims 6 to 8, wherein the thickness of the buffer layer is in the range 5 m to 20 m.

10. A waveguide as claimed in any preceding claim, wherein the second core layer is formed on the first core layer and said first core layer is formed on the substrate.

11. A waveguide as claimed in any of Claims 1 to 9, wherein the first core layer is formed on the second core layer and said second core layer is formed on the substrate.

12. A waveguide as claimed in Claim 10, wherein a further first core layer is formed on the second core layer such that the first core layer sandwiches the second core layer.

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13. A waveguide as claimed in any preceding claim, wherein the first core layer includes silica.

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14. A waveguide as claimed in ~~any~~ preceding claim, wherein the first core layer dopant includes dopant ions.

15. A waveguide as claimed in Claim 14, wherein the first core layer dopant ions include ~~tin~~ and/or cerium and/or sodium.

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16. A waveguide as claimed in any preceding claim, wherein the second core layer includes silica.

17. A waveguide as claimed in any preceding claim, wherein the second core layer includes a phosphorus oxide.

18. A waveguide as claimed in any preceding claim, wherein the second core layer dopant includes dopant ions.

19. A waveguide as claimed in Claim 18, wherein the second core layer dopant includes a mobile dopant.

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20. A waveguide as claimed in any of Claims 16 to 19, wherein the second core layer dopant includes a rare earth and/or a heavy metal and/or compounds of these elements.

21. A waveguide as claimed in Claim 20, wherein the rare earth is Erbium or Neodymium.

22. A waveguide as claimed in any preceding claim, wherein the refractive indices of the first core layer and the second core layer are substantially equal.

23. A waveguide as claimed in any preceding claim, wherein the refractive index of the waveguide core differs from that of the substrate by at least 0.05%.

24. A waveguide as claimed in any preceding claim, wherein the thickness of the first core layer is in the range 0.2 m to 30 m.

25. A waveguide as claimed in any preceding claim, wherein the thickness of the second core layer is in the range 0.2 m to 30 m.

26. A waveguide as claimed in Claim 24, wherein the width of the waveguide core lies in the range 0.4 m to 60 m.

27. A waveguide as claimed in any of Claims 8 to 26, wherein the upper cladding layer and the lower cladding layer comprise the same material.

28. A waveguide as claimed in any preceding claim, wherein the refractive index of the substrate and the refractive index of the upper cladding layer are substantially equal.

29. An optical waveguide according to any of Claims 1 to 28, wherein the first core layer includes at least 17% wt germanium dopant.

30. A method of fabricating a waveguide comprising the steps of:
providing a substrate;

forming a waveguide core on the substrate, the waveguide core comprising a first core layer and a second core layer;

forming an upper cladding layer to embed the waveguide core;

wherein the formation of the first core layer includes the doping of the first core layer with a dopant for permitting the first core layer to exhibit a photosensitive response, and the formation of the second core layer includes the doping of the second core layer with a dopant for inducing amplification of an optical signal transmitted through said waveguide core.

31. A method according to Claim 30, wherein the dopant used to permit the first core layer to exhibit a photosensitive response is a germanium dopant.

32. A method according to Claim 31, wherein the first core layer is co-doped with a boron dopant.

33. A method as claimed in any of Claims 30 to 32, wherein the formation of the substrate includes the formation of an intermediate layer formed on said substrate.

34. A method as claimed in Claim 33, wherein the formation of the intermediate layer includes the formation of a buffer layer.

35. A method as claimed in Claim 34, wherein the buffer layer is formed by thermally oxidising the substrate.

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36. A method as claimed in Claim 34 or Claim 35, wherein the formation of the intermediate layer further includes the formation of a lower cladding layer formed on said buffer layer.

37. A method as claimed in Claim 36, wherein the formation of the lower cladding layer includes doping said lower cladding layer with a dopant.

38. A method as claimed in Claim 37, wherein the dopant includes dopant ions.

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39. A method as claimed in any of Claims 30 to 38, wherein the second core layer is formed on the first core layer and wherein the first core layer is formed on the substrate.

40. A method as claimed in any of Claims 30 to 39, wherein the first core layer is formed on the second core layer and said second core layer is formed on the substrate.

41. A method as claimed in Claim 39, wherein a further first core layer is formed on the second core layer such that the first core layer sandwiches the second core layer.

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42. A method as claimed in any of Claims 30 to 41, wherein the steps of forming any one of the substrate, first core layer, the second core layer, and the upper cladding layer comprise the steps of:
depositing each layer; and
at least partially consolidating each layer.

43. A method as claimed in Claim 42, wherein any one of the substrate, the first core layer, the second core layer and the upper cladding layer partially consolidated after deposition is fully consolidated with the full consolidation of any other of the first core layer, the second core layer or the upper cladding layer.

44. A method as claimed in any of Claims 30 to 43, wherein the formation of the substrate includes the doping of the substrate with a dopant.

45. A method as claimed in any of Claims 30 to 44, wherein the dopant includes dopant ions.

46. A method as claimed in Claim 44 or Claim 45, wherein the substrate dopant includes a mobile dopant.

47. A method as claimed in Claim 45 or Claim 46, wherein said first core layer dopant ions include tin and/or cerium and/or sodium.

48. A method as claimed in any of Claims 45 to 47, wherein said second core layer dopant ions include a rare earth and/or a heavy metal and/or compounds thereof.

49. A method as claimed in Claim 48, wherein said rare earth is Erbium and/or Neodymium.

50. A method as claimed in any of Claims 30 to 49, wherein the concentration of the first core layer dopant is selectively controlled during the formation of the

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first core layer and the concentration of the second core layer dopant is selectively controlled during the formation of the second core layer so that the refractive index of the first core layer and the refractive index of the second core layer are substantially equal.

51. A method as claimed in Claim 50, wherein the concentrations of the first core layer dopant and second core layer dopant are controlled to give a refractive index for the waveguide core which differs from that of the substrate layer by at least 0.05%.

52. A method as claimed in any of Claims 34 to 51, wherein said lower cladding layer and said buffer layer are formed substantially in the same step.

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53. A method as claimed in any of Claims 42 to 52, wherein at least one of the substrate, the first core layer, the second core layer, and the upper cladding layer is deposited by a Flame Hydrolysis Deposition process and/or Chemical Vapour Deposition process.

54. A method as claimed in Claim 53, wherein the Chemical Vapour Deposition process is a Low Pressure Chemical Vapour Deposition process or a Plasma Enhanced Chemical Vapour Deposition process.

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55. A method as claimed in any of Claims 42 to 54, wherein the consolidation is by fusing using a Flame Hydrolysis Deposition burner.

56. A method as claimed in any of Claims 42 to 55, wherein the consolidation is by fusing in a furnace.

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57. A method as claimed in Claim 55 or Claim 56, wherein the step of fusing the lower cladding layer and the step of fusing the first core layer and/or the second core layer are performed simultaneously.

58. A method as claimed in any of Claims 30 to 57, wherein the waveguide core is formed from the first core layer and the second core layer using a dry etching technique and/or a photolithographic technique and/or a mechanical sawing process.

59. A method as claimed in Claim 58, wherein the dry etching technique comprises a reactive ion etching process and/or a plasma etching process and/or an ion milling process.

60. A method as claimed in any of Claims 30 to 59, wherein the waveguide core formed from the first core layer and the second core layer is square or rectangular in cross-section.

61. A method according to any of Claims 30 to 60, wherein the first core layer is doped with at least 17%wt germanium dopant.

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62. A laser waveguide with multiple core layers for transmitting an optical signal, the laser waveguide comprising a waveguide as claimed in any of claims 1 to 29, the laser waveguide further comprising:

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~~at least one grating formed in said waveguide core.~~

63. A laser waveguide as claimed in Claim 62, wherein the laser waveguide further comprises at least one optical interference mirror.

64. A laser waveguide as claimed in Claim 63, wherein the optical interference mirror is provided at the input of the waveguide.

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65. A laser waveguide as claimed in Claim 64, wherein the interference mirror is butt-coupled to or directly deposited at the input of the waveguide.

66. A laser waveguide as claimed in any of Claims 62 to 65, wherein the laser waveguide includes two mirrors and a grating.

67. A laser waveguide as claimed in any of Claims 62 to 65, wherein the laser waveguide includes one mirror and two gratings.

68. A laser waveguide as claimed in Claim 62, wherein the laser waveguide includes three gratings.

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69. A laser waveguide as claimed in any of Claims 62 to 68, wherein the grating formed is a Bragg grating.

70. A laser waveguide as claimed in any of Claims 62 to 69, wherein said grating forms an output coupler for said laser waveguide.

71. A laser waveguide as claimed in any of Claims 62 to 70 further comprising an optical interference mirror butt coupled to or directly deposited at the output of the waveguide.

72. A method of fabricating a laser waveguide, comprising forming a waveguide according to a method as claimed in any of Claims 30 to 61, the method of fabricating the laser waveguide further including the steps of: forming at least one grating in said waveguide core.

73. A method as claimed in Claim 72, further including the step of attaching at least one optical interference mirror to the waveguide.

74. A method as claimed in Claim 73, wherein the optical interference mirror is attached to an input of the waveguide.

75. A method as claimed in any of Claims 72 to 74, wherein the grating is formed using a laser operating at a wavelength in the range of 150 nm to 400 nm through a phase mask deposited on top of said upper cladding layer of the waveguide.

76. A method as claimed in Claim 75, wherein said mask is a quartz mask.

77. A method as claimed in any of Claims 72 to 74, wherein the grating is formed using a using an interference side writing technique.

78. A method as claimed in any of Claims 72 to 74, wherein the grating is formed using a direct writing technique.

79. A method as claimed in any of Claims 72 to 78, wherein the grating formed is a Bragg grating.

80. A method as claimed in any of Claims 73 to 79, wherein the optical interference mirror is butt-coupled to or directly deposited at the input of the waveguide.

81. A method as claimed in any of Claims 72 to 79, further comprising the step of attaching a second optical interference mirror to the output of the waveguide.

82. A waveguide substantially as described herein and with reference to Figs. 1A to 1C of the accompanying drawings.

83. A laser waveguide substantially as described herein and with reference to Figs. 2A and 2B of the accompanying drawings.

84. A method of fabricating a waveguide with multiple core layers substantially as described herein and with reference to Figs. 1A to 1C of the accompanying drawings.

85. A method of fabricating a laser waveguide with multiple core layers substantially as described herein and with reference to Figs. 2A and 2B of the accompanying drawings.